Trends in *Cornus florida* (Flowering dogwood) population structures since the discovery of *Discula destructiva* using FIA and field data

Forest Health Monitoring-Evaluation Monitoring Project (ISA-08-31-05-FH-14)

2007 Final Progress Report
Year 2 of a 2 Year Project

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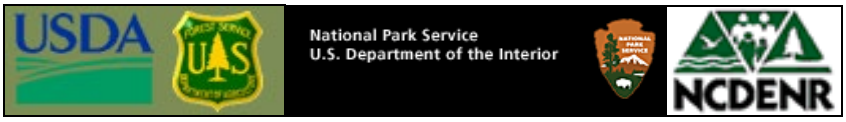


Forest Health Monitoring-Evaluation Monitoring Project Final Report:
Trends in *Cornus florida* (Flowering dogwood) population structures since the discovery of *Discula destructiva* using FIA and field data

Project Overview:

This project documented the stark changes and reductions in dogwood population structures for those five states using Forest Inventory and Analysis (FIA) data in conjunction with field transect inventories to document individual tree health and also data from yearly monitoring of about 320 permanently maintained dogwood that have been continually assessed since 1988. In total, this project consisted of three separate components: 1) FIA data analysis, 2) transect data to evaluate tree health condition, and 3) annual re-measurements of 320 permanently maintained dogwood trees in North Carolina.

Section 1: Analysis of FIA data (1980-present) for *Cornus florida* from Maryland, North Carolina, Tennessee, Virginia and West Virginia

Introduction

Flowering dogwood, *Cornus florida* (L.), is an important ornamental and wildlife tree throughout much of Eastern North America. Dogwood tends to be short in height (30 to 40 ft on good sites) with an upper diameter limit of about 16 inches (USDA, 1990). The native range of dogwood extends from Southern Canada and Maine south to Florida and as far west as Kansas and Texas (USDA, 1990). However, during the past 20-to-30 years, dogwood has been suffering from the impacts of *Discula destructiva* (Redlin), causal agent of dogwood anthracnose. Although any losses or excessive dogwood mortality evidenced cannot simply be linked directly to dogwood anthracnose, any analyses investigating an apparent decline for this species within its native range would need to consider the disease as a critical factor. This disease has decimated native stands of dogwood resulting in a population decline of approximately 50%.

<Other factors affecting dogwoods>
- Diseases
- Insects
- Pollution

Unfortunately, since very little research has been conducted on impacts since the general pandemics experienced during the 1980's and 1990's the actual losses remain unknown and generally undocumented in the current literature. The purpose of this study was to evaluate the change in dogwood numbers and then predict future mortality. Analyses and predictions were made based on the spatial patterns of dogwood occurrence and reductions and their relationships to various ecological and environmental factors thought to be important in disease development. This project consists of three different linked databases for dogwood

Methods and Materials

For this project, Forest Inventory and Analysis (FIA) data for Maryland, North Carolina, Tennessee, Virginia and West Virginia were analyzed to determine what, if any, changes have occurred with the population structure of dogwoods since the discovery of *Discula destructiva*. Only the three most recent measurement cycles of FIA data were obtained covering the years from just prior to discovery of mortality due to the disease where possible and continuing to the present date. The year(s) of measurement for each state are listed in Table 1. For analyses, measurement years were grouped into three cycles: **a.** Cycle 1 (years concurrent with or just prior to introduction of *Discula destructiva*), **b.** Cycle 2 (years concurrent with the general dogwood anthracnose pandemic), and, **c.** Cycle 3 (the most recent FIA data available online). State forest health specialists were contacted for each state to confirm or reject the assumption that data for Cycle 1 was not significantly contaminated (i.e. mortality was considered to still have been at an expected baseline level for dogwood). Lastly, only plots with at least one living or dead dogwood in any of the three measurement cycles were used.

The FIA data was downloaded from the Internet using the Forest Inventory Mapmaker v 2.1 (NIMS FIADB Downloadable Database (Available HTTP: http://ncrs2.fs.fed.us/4801/fiadb/index.htm)).

-description of FIA plot system

-software used for analyses

-statistics and confidence intervals/alpha levels for significance

<Plot Descriptions>

Descriptions of the methods and data collection procedures is outside of the scope of this report and are published elsewhere but also are available online at http://www.fia.fs.fed.us/library/field-guides-methods-proc/.

-Fixed area plots only

-How were fixed area plots standardized across varying methods of data collection?

-Only re-measured plots were used

-# of plots per year

-Why the numbers are different even though only re-measured plots were used

-make sure if a plot in cycle 2 or cycle 3 added for first time that plot is included in all 3 cycles

Plots were dropped only when they were not re-measured after establishment. The total number and percent of FIA plots that either never contained dogwoods or were dropped from the database Cycle 1, Cycle 2 and Cycle 3 data were 8,673 (40.6%), 11,744 (46.6%), and 5,996 (38.9%), of the total number of FIA plots for the five states, respectively.

<Description of database>

-What had to be calculated?

-Energy index

-Hazard Rating (Anderson, *et al*.,19xx)

-What kinds of errors had to be fixed?

-Aspect > 360°

-Elevation

-Incorrect measurement year

Table 1: FIA data structure for year(s) of measurement and plot number per state. Also listed are the total number and percent of FIA plots and the number of dropped plots.

	Cycle 1 (1980's)			Cycle 2 (1990's)			Cycle 3 (2000's)		
State	**Year(s)**	**# Plots**	**(%)**	**Year(s)**	**# Plots**	**(%)**	**Year(s)**	**# Plots**	**(%)**
MD	1983	239		1999	465		2004	57	
NC	1984	5385		1990	5623		1999-2002	4038	
TN	1988-1989	2294		1996-1999	2805		1999-2004	2189	
VA	1984	4265		1992	4218		1997-2002	3052	
WV	1987	492		2000	361		2004	76	
Total		**12,675**	**(59.4%)**		**13,472**	**(53.4%)**		**9,412**	**(61.1%)**
							Sub-total	**35,559**	
Dropped Plots		**8,673**	**(40.6%)**		**11,744**	**(46.6%)**		**5,996**	**(38.9%)**
All FIA Plots		**21,348**			**25,216**			**15,408**	
							Total	**61,972**	

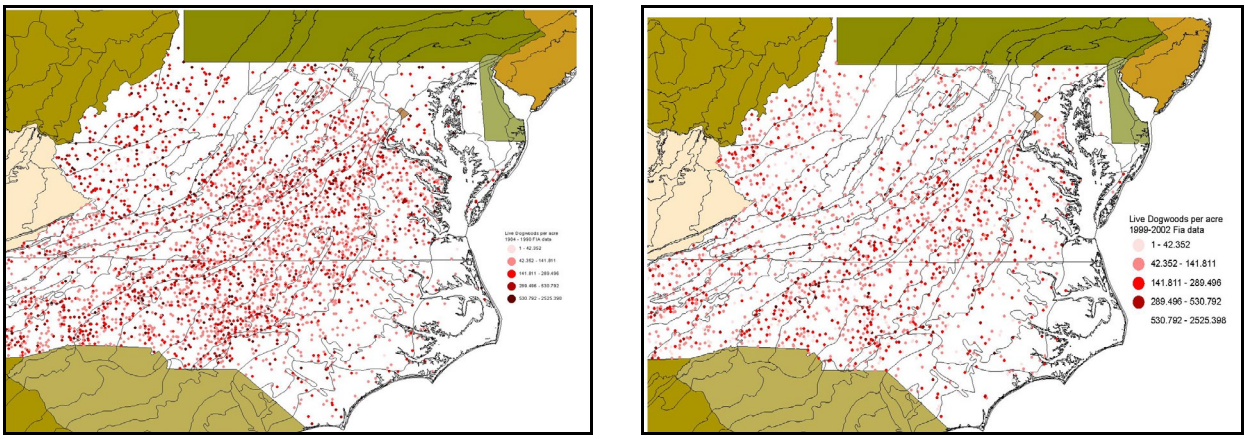
Table 2: List of discovery year of *Discula destructiva*, whether or not Cycle 1 data was contaminated due to anthracnose, and the name of the state pest specialist consulted for opinion.

State	**Year of Infestation First Discovered**	**# Counties**	**Cycle 1 Data Considered Contaminated?**	**Name of State Pest Expert Asked To Confirm/Deny Contamination of Cycle 1[1]**
MD	1984	1	No	Bob Rabaglia
NC	1987	1	No	Brian Heath
TN	1988	2	Yes	Bruce Kauffman
VA	1986	1	No	Chris Asaro
WV	1985	2	No	Clark Haynes

1-Contacted in 2006

Table 2. Total number of *Cornus florida* per state and percent change from the 1980's to 2000's obtained directly from the FIA website.

State	Cycle 1 (1980's)	Cycle 2 (1990's)	Change from Cycle 1-Cycle 2	Cycle 3 (2000's)	Change from Cycle 2-to-3	1-to-3
MD	67,600,000	33,200,000	-50.9%	25,200,000	-24.1%	-63.0%
NC	938,000,000	872,000,000	-7.0%	434,000,000	-50.2%	-53.7%
TN	764,000,000	584,000,000	-23.6%	361,000,000	-38.2%	-52.8%
VA	923,000,000	878,000,000	-4.9%	447,000,000	-49.1%	-51.6%
WV	522,000,000	181,500,000	-65.2%	182,000,000	0.3%	-65.3%
Total	**3,214,600,000**	**2,548,700,000**	**-20.7%**	**1,449,200,000**	**-43.2%**	**-54.9%**



A. B.

Figure 1. Number of live dogwood trees per acre on FIA plots during Cycle 1 (A) and Cycle 3 (B). Cycle 2 data not shown.

Table 3. Distribution of percent dogwood trees by two-inch diameter classes for MD, NC, TN, VA and WV from FIA measurement cycles 1 thru 3.

	Two-Inch Diameter Class					
	2"	4"	6"	8"	10"	12+"
Cycle 1 (1980's)	84.0%	14.5%	1.9%	0.2%	0.2%	0.0%
Cycle 2 (1990's)	82.5%	15.1%	2.2%	0.2%	0.0%	0.0%
Cycle 3 (2000's)	81.6%	15.8%	2.4%	0.0%	0.0%	0.0%

Table 3. Mean and standard error (SE) of the number of live dogwood per acre on FIA plots for Cycle 1, Cycle 2 and Cycle 3.

State	Cycle 1 Mean (SE)	Cycle 2 Mean (SE)	Cycle 3 Mean (SE)	Change from Cycle 1 to Cycle 3
MD	45.2 (7.8)	13.5 (2.0)	9.6 (3.8)	-78.8%
NC	46.9 (1.5)	41.7 (1.4)	20.6 (1.1)	-56.1%
TN	58.5 (2.8)	36.1 (1.5)	22.6 (1.3)	-61.4%
VA	58.1 (1.8)	55.2 (1.7)	28.0 (1.4)	-51.8%
WV	226.9 (9.9)	66.6 (3.9)	60.0 (10.9)	-73.6%
Average	87.1	42.6	28.2	-64.3%

Table 4. Mean and standard error (SE) of the number of dead dogwood per acre on FIA plots from Cycle 1 to Cycle 3.

State	Cycle 1 Mean (SE)	Cycle 2 Mean (SE)	Cycle 3 Mean (SE)	Change from Cycle 1 to Cycle 3
MD	0.10 (0.05)	17.01 (3.30)	5.47 (2.67)	+**5,370.0%**
NC	0.31 (0.07)	0.18 (0.04)	0.51 (0.10)	+**64.5%**
TN	2.38 (0.19)	0.51 (0.11)	0.09 (0.01)	**-96.2%**
VA	0.22 (0.06)	0.14 (0.04)	0.41 (0.09)	+**86.4%**
WV	0.06 (0.05)	0.58 (0.13)	0.24 (0.14)	**+300.0%**
Mean	0.61	3.68	1.34	+1,144.9%

Table 5. Mean (standard error) live dogwoods per acre per eco-region subsection from each measurement cycle.

State	Ecoregion	Cycle 1	Cycle 2	Cycle 3	Change from Cycle 1 to Cycle 3
MD					
	Allegheny Mts.	4.4 (4.4)	2.9 (2.0)	0.0 (0.0)	-100.0%
	Blue Ridge Mts.	38.4 (33.1)	0.0 (0.0)	0.0 (0.0)	-100.0%
	Coastal Plain	26.3 (6.6)	9.2 (1.8)	3.1 (2.5)	-88.2%
	N. Ridge & Valley	155.9 (45.9)	18.2 (6.2)	18.7 (12.3)	-88.0%
	Piedmont	110.0 (35.8)	34.3 (8.4)	30.0 (16.6)	-72.7%
NC					
	Blue Ridge Mts.	76.1 (4.9)	67.5 (4.4)	17.7 (2.0)	-76.7%
	Coastal Plain	14.9 (1.2)	13.6 (1.1)	8.2 (1.0)	-45.0%
	Piedmont	86.2 (3.2)	79.4 (3.3)	46.3 (2.7)	-46.3%
TN					
	Cumberland Plateau	74.7 (6.4)	38.0 (3.6)	21.4 (3.0)	-71.4%
	East Tennessee	70.6 (7.0)	42.5 (3.3)	27.9 (2.8)	-60.5%
	Middle Tennessee	48.0 (3.7)	36.7 (2.6)	23.1 (2.2)	-51.9%
	West Tennessee	44.5 (4.9)	25.4 (2.6)	16.0 (2.2)	-64.0%
VA					
	Blue Ridge Mts.	64.1 (3.4)	58.1 (3.0)	22.5 (2.0)	-64.9%
	Coastal Plain	35.8 (2.8)	34.3 (2.9)	20.1 (2.7)	-43.9%
	Piedmont	66.6 (2.9)	65.5 (2.9)	37.0 (2.4)	-44.4%
WV					
	Allegheny Mts.	244.5 (26.7)	43.0 (2.9)	14.2 (9.1)	-94.2%
	N. Cumberland Mts.	182.0 (15.0)	58.4 (7.7)	35.4 (10.0)	-80.5%
	N. Ridge & Valley	297.9 (28.7)	65.8 (12.1)	98.7 (57.0)	-66.9%
	S. Allegheny Plateau	232.7 (16.3)	77.7 (5.2)	82.7 (16.4)	-64.5%

Table 6. Mean (standard error) dogwoods per acre per eco-region subsection from each measurement cycle.

State	Ecoregion	Cycle 1	Cycle 2	Cycle 3	Change
MD					
	Allegheny Mts.	0.00 (0.00)	1.41 (1.41)	0.00 (0.00)	+0.0%
	Blue Ridge Mts.	0.00 (0.00)	16.47 (14.45)	1.20 (0.34)	-92.7%
	Coastal Plain	0.11 (0.07)	10.54 (2.92)	7.40 (4.15)	+6,627.3%
	N. Ridge & Valley	0.33 (0.33)	68.30 (24.48)	0.00 (0.00)	-100.0%
	Piedmont	0.00 (0.00)	19.74 (6.78)	7.50 (7.50)	-62.0%
NC					
	Blue Ridge Mts.	0.49 (0.25)	0.36 (0.18)	1.20 (0.34)	+144.9%
	Coastal Plain	0.18 (0.08)	0.07 (0.03)	0.04 (0.03)	-77.8%
	Piedmont	0.43 (0.14)	0.30 (0.08)	0.77 (0.22)	+79.1%
TN					
	Cumberland Plateau	3.16 (0.45)	0.81 (0.36)	0.04 (0.01)	-98.7%
	East Tennessee	4.10 (0.56)	0.73 (0.26)	0.14 (0.05)	-96.6%
	Middle Tennessee	1.07 (0.15)	0.43 (0.16)	0.09 (0.02)	-91.6%
	West Tennessee	1.62 (0.28)	0.16 (0.10)	0.07 (0.02)	-95.7%
VA					
	Blue Ridge Mts.	0.15 (0.08)	0.21 (0.08)	0.63 (0.18)	+320.0%
	Coastal Plain	0.29 (0.15)	0.13 (0.08)	0.30 (0.25)	+3.4%
	Piedmont	0.22 (0.10)	0.10 (0.05)	0.26 (0.10)	+18.2%
WV					
	Allegheny Mts.	0.00 (0.00)	0.98 (0.68)	0.00 (0.00)	+0.0%
	N. Cumberland Mts.	0.19 (0.14)	1.04 (0.30)	0.50 (0.35)	+163.2%
	N. Ridge & Valley	0.00 (0.00)	0.36 (0.20)	0.00 (0.00)	+0.0%
	S. Allegheny Plateau	0.00 (0.00)	0.26 (0.10)	0.19 (0.19)	+100.0%

Table 7. Mean (standard error) live dogwood trees per acre grouped by risk of based on the dogwood anthracnose risk map.

	Disease Hazard Class					
Cycle	Very Low	Low	Moderate	High	Severe	None
1	46.2 (1.2)	98.5 (4.9)	78.0 (2.8)	101.9 (8.3)	54.9 (5.9)	5.1 (5.1)
2	38.2 (1.0)	63.9 (3.1)	54.1 (2.1)	56.6 (6.2)	42.3 (4.7)	4.4 (4.4)
3	22.4 (1.0)	35.0 (2.4)	24.3 (1.4)	18.8 (2.7)	14.1 (2.4)	18.8 (12.3)
Observed change from Cycle 1 to Cycle 3:						
	-51.5%	-64.5%	-68.8%	-81.6%	-74.3%	+268.8%
Expected mortality based on disease hazard class:						
	+0.0%	-25.0%	-50.0%	-75.0%	-100.0%	+0.0%
Difference between expected and observed mortality:						
	-51.5%	-39.5%	-18.8%	-6.6%	+25.7%	+268.8%
Number of trees in each disease hazard class by cycle:						
Cycle						
1	371,896.6	131,705.2	193,049.5	34,534.2	26,007.1	30.5
2	333,117.2	90,818.2	136,124.9	18,344.5	20,363.0	30.6
3	114,517.0	38,104.5	55,946.3	7,527.6	6,953.2	150.0
Predicted number of trees based on hazard class for Cycle 3:						
3	371,899.6	98,778.9	96,524.8	8,633.6	0.0	30.5
Difference between predicted and observed mortality for Cycle 3:						
3	-257,379.6	-60,674.4	-40,578.5	-1,106.0	+6,953.2	+119.5

Table 8. Change in the number (standard error) of dogwood per acre from 1984 to 2004 based on elevation.

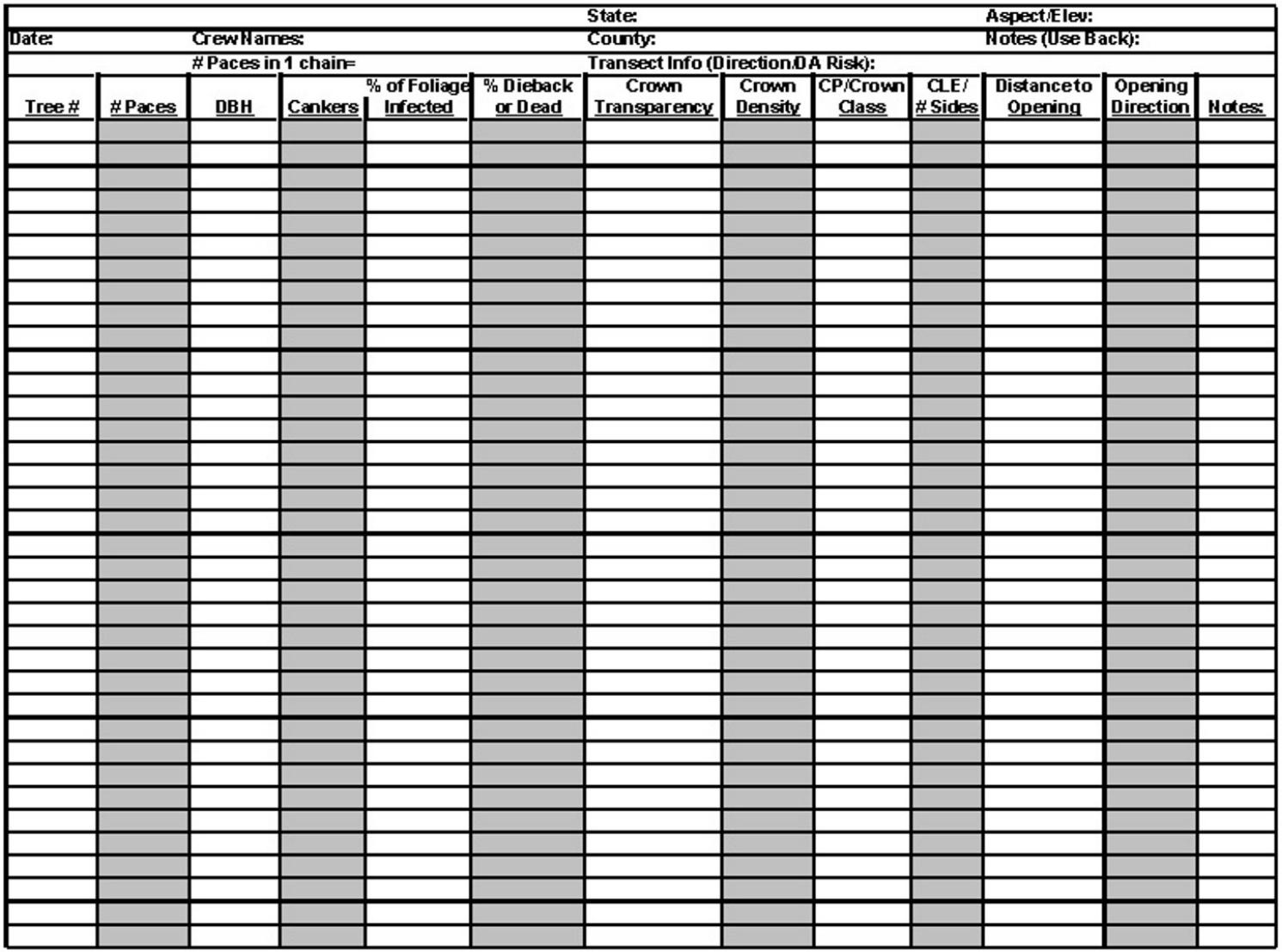
	Elevation (feet)					
	0	500	1000	1500	3000	5000
Year						
1984	107.9 (3.6)	131.9 (4.6)	138.8 (6.4)	144.1 (4.4)	144.8 (10.1)	69.3 (36.2)
1994	81.0 (2.4)	94.9 (2.7)	97.6 (3.7)	89.6 (2.8)	84.9 (7.7)	50.7 (35.2)
2004	54.2 (4.1)	58.0 (4.2)	56.4 (5.8)	35.1 (4.6)	24.9 (12.0)	32.2 (35.7)
20-year Change						

Discussion

The purpose of this project was to describe the change in Flowering dogwood since the discovery of dogwood anthracnose. Given the wide geographic range of the tree species in North America and the various land ownerships the only practical means to achieve the goal was to utilize existing and readily accessible Forest Inventory and Analysis (FIA) database.

Section 2: Report on Fixed-Area Transect Data of Flowering Dogwood Tree Health in North Carolina, Tennessee and West Virginia

In 2005, 67 points were established to evaluate health and topographical position of dogwoods in North Carolina and Tennessee. Locations were stratified based on a previously developed risk rating model for North Carolina (Figure 3), Tennessee (Figure 4), and West Virginia (Figure 5). Points consisted of four 330' transects (5 chains) that were 6' wide in the north, east, south and west directions. Along transects, only flowering dogwood living or dead but tall enough to have a measurable diameter (DBH $\geq$ 0.1 inches) were tallied. Only dogwoods where the pith or tree base in the case of downed trees intersected or fell completely within the six-foot-wide transects were counted as "in trees." Standard information was collected for each point including aspect, elevation and GPS data and for all intersected dogwood using a data sheet developed for this project (Figure 6).



State: Aspect/Elev:
Date: Crew Names: County: Notes (Use Back):
Paces in 1 chain= Transect Info (Direction/DA Risk):

Tree #	# Paces	DBH	Cankers	% of Foliage Infected	% Dieback or Dead	Crown Transparency	Crown Density	CP/Crown Class	CLE/ # Sides	Distance to Opening	Opening Direction	Notes:

Figure 6. Dogwood Anthracnose Field Data Sheet

A strong negative trend was discovered between the number of dogwoods and the distance to an opening (Figure 7). As might be expected, the greater the hazard from very low to severe, the closer to an opening did the dogwoods occur. However, within each dogwood anthracnose hazard rating class the relative proportion of live trees increased while the relative proportion of dead trees decreased, except in the severe risk areas (Figure 8). These two main findings relating to distance to crown openings and relative tree health within each risk class are expected to frame further work for the following year. Looking strictly at dieback class, approximately 33% of dogwoods intersected on the transects were dead and 50% were classified as "healthy," i.e. dieback ≤25% (Figure 9).

Component 3 is approximately one-third completed and will be completed by August 2006.

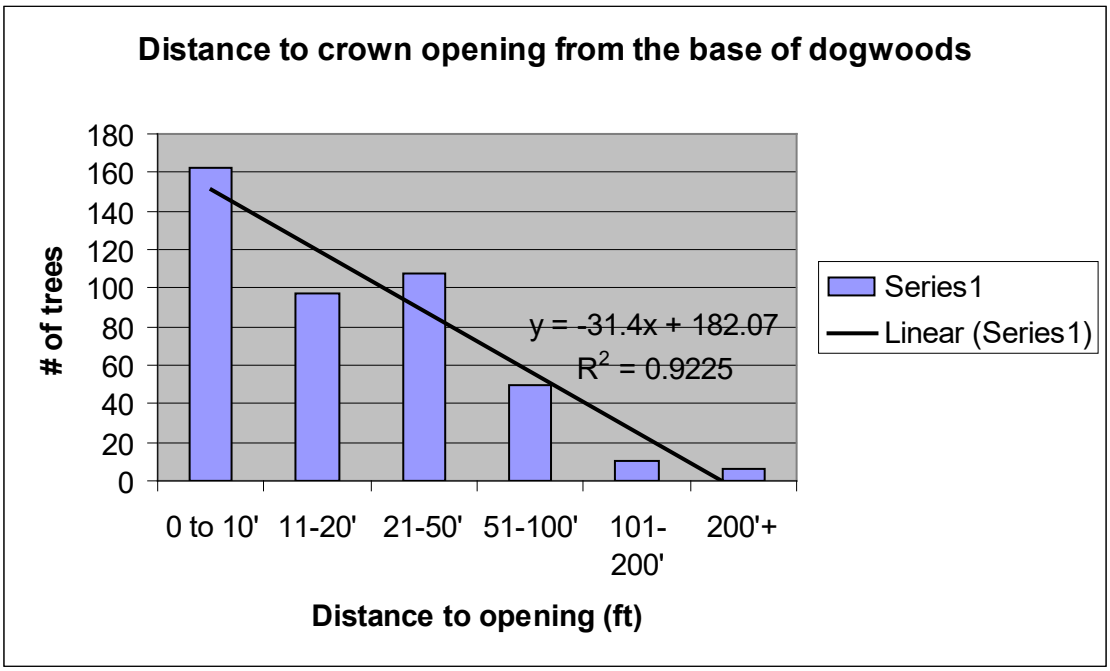


Figure 7. Distance (ft) to crown opening from the base of dogwood trees.

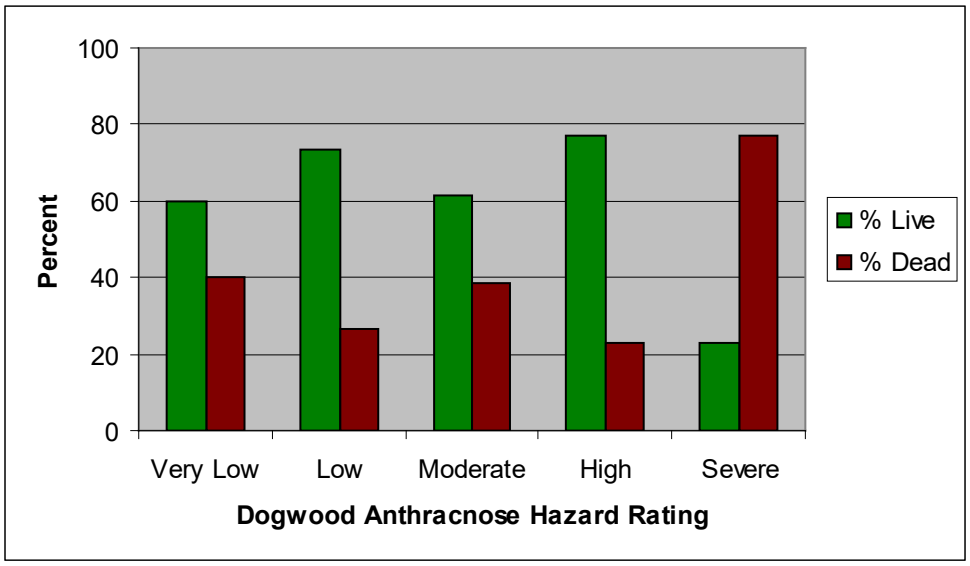


Figure 8. Percent of dogwoods that scored as alive or dead in each of the dogwood anthracnose hazard rating classes (Very low n=67, Low n=223, Moderate n=297, High n=61 and Severe n=13).

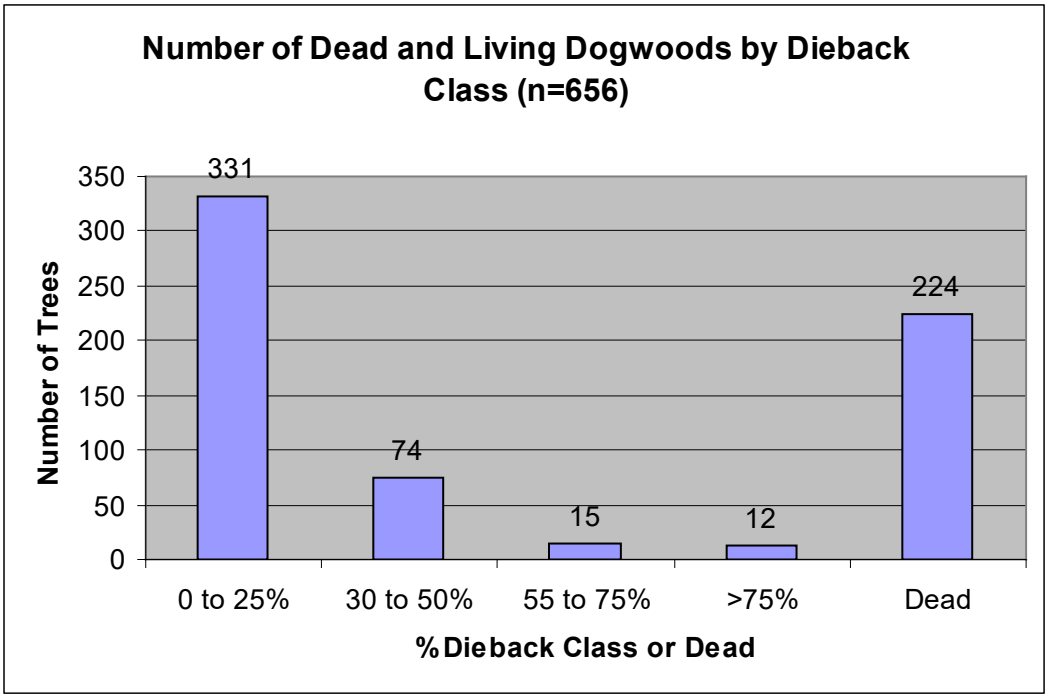


Figure 9. Number of trees in 25%-dieback classes or dead.

Section 3: Report on Nineteen Continuous Years of Monitoring of Permanent Dogwood Anthracnose Impact Plots in North Carolina

Introduction

<Description of dogwood>
Flowering dogwood, *Cornus florida* (L.), is an important ornamental and wildlife tree throughout much of Eastern North America. The native range of dogwood extends from Southern Canada and Maine south to Florida and as far west as Kansas and Texas (USDA, 1990).
<Occurrence of dogwood>
However, during the past 20-to-30 years, dogwood has been suffering from the impacts of *Discula destructiva* (Redlin), causal agent of dogwood anthracnose. Although any losses or excessive dogwood mortality evidenced cannot simply be linked directly to dogwood anthracnose, any analyses investigating an apparent decline for this species within its native range would need to consider the disease as a probable critical factor. This disease has decimated native stands of dogwood resulting in a population decline of approximately 50% since the late.

<Other factors affecting dogwoods>
- Diseases
- Insects
- Pollution

Unfortunately, since very little research has been conducted on impacts since the general pandemics experienced during the 1980's and 1990's the actual losses remain unknown and generally undocumented in the current literature. The purpose of this study was to evaluate the change in dogwood numbers and then predict future mortality. Analyses and predictions were made based on the spatial patterns of dogwood occurrence and reductions and their relationships to various ecological and environmental factors thought to be important in disease development.

Methods

From 1988 to 2006 the North Carolina Division of Forest Resources has maintained permanent monitoring plots to track the condition of Flowering dogwood, particularly in the mountainous, western parts of the state. The methods and data forms used to collect data were previously published (Knighten and Anderson, eds, 1993) but the results from 1993 through 2006 have not been formerly reported (NCDFR, unpublished data). Plots consisted of the closest ten Flowering dogwood trees on a random stratified 15-minute grid system. Locations were determined with the aide of topographic maps. If fewer than 10 trees could be located near plot centers the locations were still retained but if no dogwood were present in a one-mile radius the plots were abandoned. If all 10 trees died, plots were also abandoned and not re-visited. The total number of trees tracked in North Carolina was 293 trees on 31 plots. These 31 plots are were part of a larger regional project involving 210 plots across seven states in the Southeastern U.S., but only North Carolina has maintained plots continuously since 1993 on a yearly basis.

The basic tree health information collected between 1993 and 2005 was dieback class, DBH, tree height, stem infections, and whether a leaf sample was obtained to culture Discula. Once a tree was laboratory-confirmed as being Discula positive, that tree was maintained as "positively infected" in the database but no longer re-sampled to culture the fungus. Crown ratings were based on a six-point scale from 0-to-5 based on the Mielke-Langdon dieback classes (Mielke and Langdon, 1984):

0 = Dead
1 = >75% Foliage affected
2 = 51-75% Foliage affected
3 = 26-50% Foliage affected
5 = Healthy

Results

As of 2006, 245 of the 293 (83.6%) Flowering dogwoods in the permanent plots had died (Figure 10). Of the dead trees, 55 died but were never found to be positive for Discula (23.2%) and 129 died without exhibiting signs of cankering (54.4%). A total of 215 trees (73.4%) tested positive for Discula between 1988 and 2005. Fewer trees exhibited cankering during the same time period, with only 130 trees showing signs (44.4%). Between 1988 and 2005, the peak year for positive new infections was 1992 with a smaller, secondary peak in 1999 (Figure 10). Peak mortality occurred in 1998 but trees continued to die each year from 1989 through 2006 (Figures 10 and 11). Of the 172 trees that died and were Discula-positive, the mean number of years between infection and mortality was 4.8 ± 3.3 years. Of the 98 trees that showed cankering and died, the mean difference between cankering becoming evident and mortality was 3.7 ± 3.1 years.

Of the 56 trees still alive as of 2005, 44 were confirmed Discula positive (78.6%) and 32 had cankering (57.1%). Since 2000, mean crown rating for living trees has remained relatively constant, with means ranging from 2.3 to 2.4 (Figure 11). Prior to 2000 mean crown rating had declined steadily from a high of 5.0 in 1989 to a low of 2.3 in 2002. As of 2000, no trees were rated "healthy," or a crown rating equal to five (Figure 11). No trends can be discerned in crown rating data between 1988 and 1992 data however, because of missing data for those years from several plots (data not shown). Of surviving trees, those infected during the secondary peak infection year of 1999 are in the worst health condition.

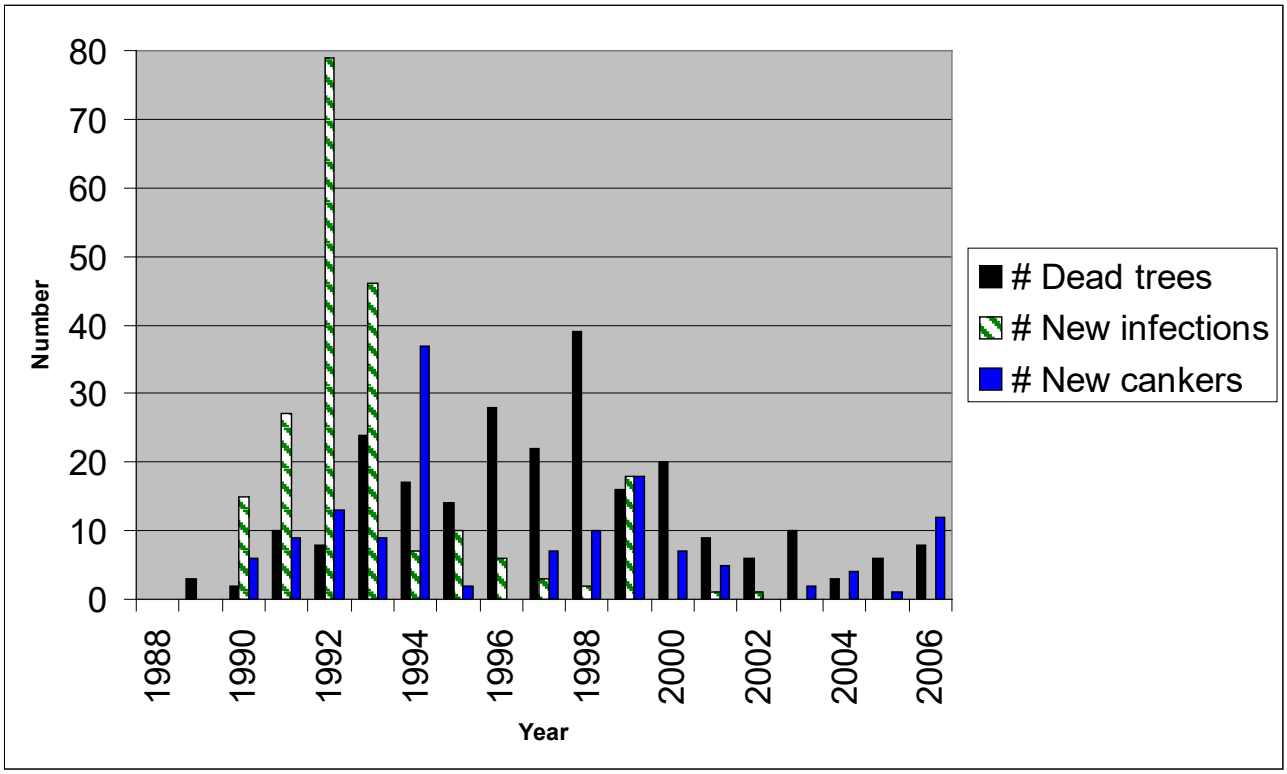


Figure 10. Change in number of dead trees, new Discula infections, and new stem cankers per year on Flowering dogwood from permanent plots (1988-2006).

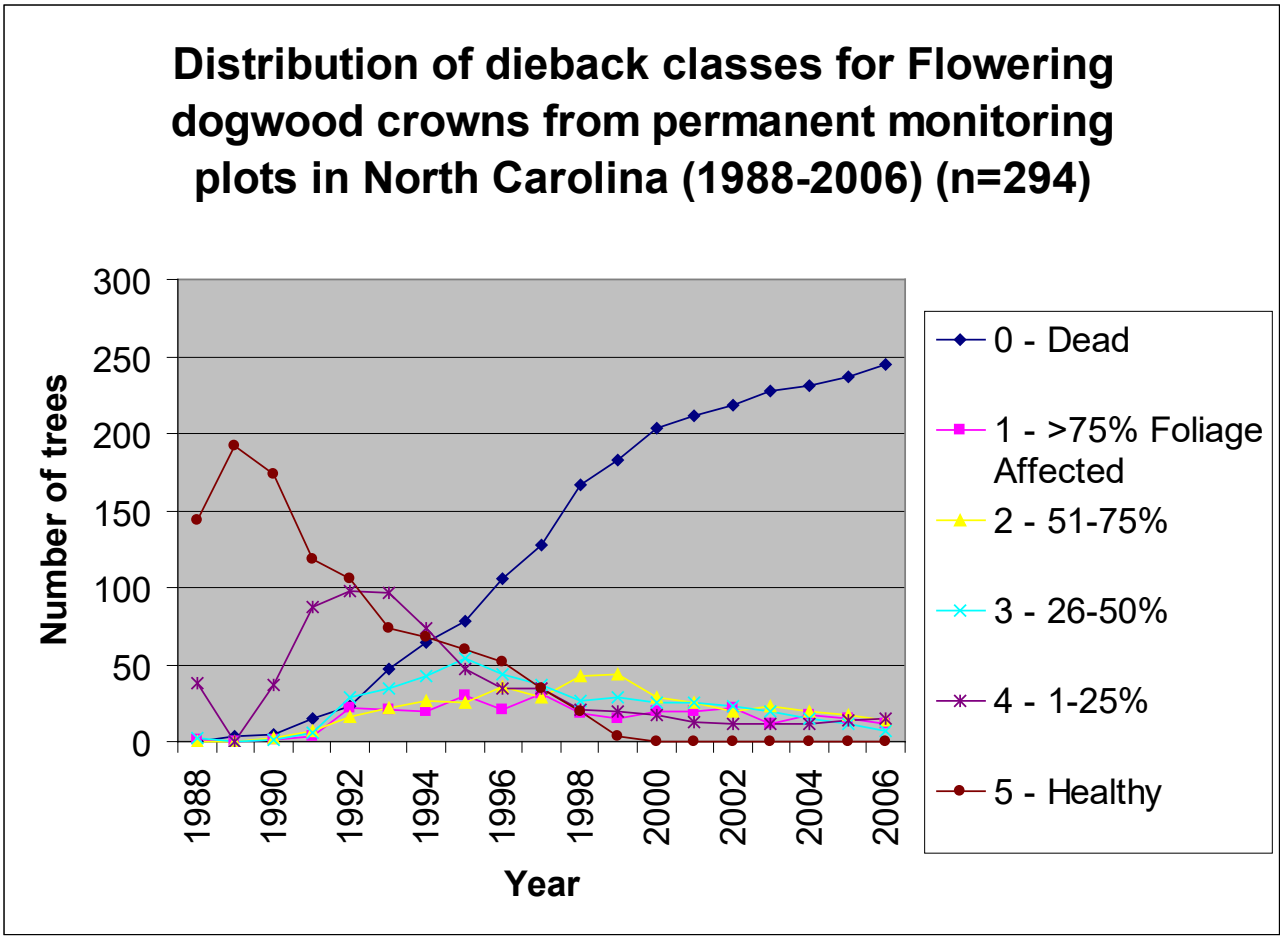


Figure 11. Distribution of dieback classes for Flowering dogwood crowns from permanent plots (1988-2006).

Table 1r. Tree tallies

Discussion and Conclusions

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Appendix 1. Dogwood Anthracnose Hazard Rating System

Hazard Class	Description
Severe	Areas of all aspects with elevation between 3,000 and 5,000 feet
High	Areas with north aspect and elevation between 1,500 and 3,000 feet
Moderate	Areas with north aspect and elevation between 1,000 and 1,500 feet; Areas with all aspects except north and elevation between 1,500 and 3,000 feet; Or, stream buffers 30 meters either side of a stream
Low	Areas with north aspect and elevation between 500 and 1,000 feet; Or, areas with all aspects except north and elevation between 1,000 and 1,500 feet
Very Low	Blue Grass Area in Kentucky; Or, all other areas
None	Areas with elevation above 5,000 feet (no dogwood present)